Plant Ecology **149:** 169–180, 2000.

Patterns of plant species richness in pasture lands of the northeast United States

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Received 28 September 1999; accepted in revised form 9 May 2000

Key words: Comparisons with other grasslands, Environmental variables, Management intensive grazing, Land management, Plant diversity, Transient species

Abstract

Pasture lands are an important facet of land use in the northeast United States, yet little is known about their recent diversity. To answer some fundamental questions about the diversity of these pasture lands, we designed a broad survey to document plant species richness using an intensive, multi scale sampling method. We also wanted to learn whether environmental (soils or climate) or land management variables could help explain patterns of species richness. A total of 17 farms, encompassing 37 pastures, were sampled in New York , Pennsylvania, Vermont, Maryland, Massachusetts and Connecticut during July and August 1998. We positively identified a total of 161 different plant species across the study region. Species richness averaged 31.7 ± 1.1 on pastures. Infrequent, transient species that were mostly perennial and annual forbs accounted for $\sim 90\%$ of the species richness. Except for a subjective rating of grazing intensity, land management methods were not good predictors of species richness. Over time, it appears that grazing neither reduces nor increases species richness in pastures. Of the environmental variables measured, only soil P explained a significant amount of the variation in species richness. Soil P was inversely related to species richness at the $1m^2$ scale. Percent SOM was positively associated with species richness at this scale, although weakly. At larger spatial scales, we suggest that patterns of species richness are best explained by the species diversity of soil seed banks, or seed rain, and stochastic recruitment of these species into existing vegetation.

Introduction

Pasture and range lands are important components of land use in many parts of the world. In fact, some estimates suggest that roughly 50% of the Earth's terrestrial surface is grazed by large herbivores (Menke & Bradford 1992). In the northeast United States, grazed pasture accounts for 8% of the northeast's non federal rural land $\sim$ 3.5 million ha (USDA 1994) and is therefore a significant contributor to livestock production in this region. Although pasture is not as abundant as it once was in the 1800s and early 1900s (Foster et al. 1998), pasture lands have received increasing interest in recent years as northeast farmers are relying more on intensive grazing to supply forage for cattle (Fales et al. 1993).

Although much is known about the ecology and diversity of pastures in Great Britain and other parts of Europe (Chippindale & Miltion 1934; Champness & Morris 1948; Forbes et al. 1980; Leps et al. 1982; Grime et al. 1988), we know little about their counterparts in the northeast United States. Most studies in this region have instead focused on how plant diversity changed following crop land abandonment (Oosting 1942; Quarterman 1957; Bazzaz 1968; Bard 1972; Bazzaz 1975; Mellinger & McNaughton 1975). More information about the ecology and diversity of northeast pastures is needed. Recently, some studies have linked increased productivity, stability and nutrient retention to high plant diversity in grasslands (Frank & McNaughton 1991; Naeem et al. 1994; Tilman & Downing 1994; Tilman et al. 1996, 1997; Hooper &

Vitousek 1998; Hector et al. 1999). If such effects apply to northeast pastures, managing pastures for high plant diversity might benefit producers who depend on intensive grazing to supply forage for cattle. First, we need better baseline information about levels of plant diversity in pasture and the variables that influence this diversity before knowledgeable management decisions can be made.

Given the lack of information on the ecology of northeast pastures, we designed a broad vegetation survey to answer some fundamental questions about their diversity. First, we sought to document plant species richness across a broad spectrum of northeast pastures using an intensive, multi scale sampling method. Secondly, we wanted to determine whether environmental variables (soils or climate) or land management methods could help explain these patterns of species richness. To help us understand the effect of grazing on plant diversity, we compared how species richness in our grazed pastures compared with published data from ungrazed, old fields in the eastern US. The rationale behind this comparison is that most pastures, like old fields, were once crop land. We reasoned that if diversity changed at different rates in pasture compared with old field after conversion from crop land, then this difference might be due, in part, to the effects of grazing.

Methods

Study sites

We sampled a total of 37 pastures on 17 farms during July and August 1998. Because the primary goal of this survey was to sample plant richness over a broad array of farms, selection criteria for inclusion were not stringent. If grazing accounted for at least 30% of the annual diet for cattle, the farm could be included. All farms were located in the northeast United States between 39–43° N and 72–78° W. Elevation above sea level and general climatic characteristics (mean annual precipitation and temperature) were collected from the nearest weather station (Table 1). Overall, the northeast is a cool, humid region of plateaus, plains and mountains. In most of the region, one half the precipitation falls in the freeze-free season, which ranges from 110–170 days (USDA, 1981). Soils in the study region are dominated by Ochrepts, Orthods and Aqualfs (USDA, 1981). We sampled two pastures on each farm except a farm in Vermont (#17) where we sampled five pastures. Pasture size ranged from 2–25 ha with an average between 4–6 ha. All pastures had been converted from crop land - usually corn. Methods of pasture conversion typically involved either no till seeding of selected pasture forages into existing sod or conventional seeding into a prepared seedbed. Seed mixes usually consisted of two or three grasses and a legume. The time since pastures were converted from crop land ranged from 2- 50 years with an average 16.3 years. All sites were grazed by cattle, although periodic grazing by white-tailed deer (*Odocoileus virginianus*) is common. Besides off take from grazing, farmers also harvested most pastures for hay at least once during the growing season.

Seven of the 17 farms sampled were beef cattle operations and ten were dairy. Two recently planted pastures had not been grazed in 1998. Stocking densities (animals per unit area) on most farms averaged approximately 2.5 animals / hectare. Forage from grazing made up approximately 30–50% of the annual diet for dairy cattle and 80% for beef cattle. Cattle were usually grazed from late April until October, but two of the beef farms were grazed year-round. We took general information on farm management from each farmer, e.g., fertilizer and herbicide use, seeding history, feeding schedules and pasture age. Using data from the literature, we compared species richness of ungrazed sites that had been abandoned from agricultural use to our grazed pastures. We chose studies that evaluated how species diversity changed after over time using differently aged old fields in North Carolina (Oosting 1942), Illinois (Bazzaz 1968; 1975) and New York (Mellinger & McNaughton 1975).

Sampling

Within farms, pastures selected for sampling were chosen to be as disparate as possible regarding age, management history, topography or soils. We used a modified Whittaker Plot method to sample plant richness in each pasture (Stohlgren et al. 1995). This method measures how plant richness changes over four spatial scales (1 m^2, 10 m^2, 100 m^2, 1000 m^2). In each pasture, one 20 $\times$ 50 m plot was established in a random location. Nested within this 1000 m^2 plot are ten 1 m^2 plots, two 10 m^2 and one 100 m^2 plot. Percent cover of each species plus bare ground was recorded in each 1 m^2 plot. The larger plots were then successively searched for new species not found in the smaller plots. Percent importance values for each species were calculated by: (relative frequency + rel-

Table 1. Site and selected soil variables for the 17 farms and 37 associated pastures surveyed in 1998. Site variables are elevation above sea level, mean annual precipitation and temperature recorded from closest weather station. Abbreviations are: CT – Connecticut, MA – Massachusetts, MD – Maryland, NY - - New York, PA – Pennsylvania and VT – Vermont.

Farm	State	Site variables			Pasture	Soil variables								
		Elevation (m)	Precip. (mm)	Temp. (°C)	(#)	pH ($kg\ ha^{-1}$)	P (meq/100 g)	K (meq/100 g)	CEC (%)	OM (%)	Sand (%)	Silt (%)	Clay	Class
1	CT	170	1090	8.6	1	6.6	248	0.38	9.0	4.2	47	40	13	loam
					2	6.8	205	0.39	8.5	3.6	50	36	14	loam
2	MA	190	1260	7.8	3	6.6	492	0.48	11.6	7.6	63	31	7	sandy loam
					4	6.9	316	0.65	9.7	6.7	58	34	8	sandy loam
3	MD	160	960	11.7	5	6.6	67	0.65	9.8	4.8	24	52	24	silt loam
					6	6.9	81	0.38	6.9	2.3	27	45	28	clay loam
4	MD	160	960	11.7	7	6.6	27	0.20	10.6	5.2	25	52	23	silt loam
					8	6.5	55	0.33	8.2	4.8	26	50	24	loam
5	MD	100	1210	12.8	9	6.4	72	0.62	10.0	5.9	45	42	13	loam
					10	5.8	157	0.40	9.4	5.1	31	48	22	loam
6	NY	260	900	8.2	11	7.4	161	0.47	17.0	3.7	48	36	16	loam
					12	7.2	306	0.69	15.6	4.9	56	32	12	sandy loam
7	NY	310	1030	7.3	13	6.5	268	0.55	11.9	11.2	40	46	14	loam
					14	5.3	45	0.23	13.7	9.1	47	37	16	loam
8	NY	260	900	8.2	15	6.2	248	0.34	9.5	4.3	46	42	13	loam
					16	6.9	427	0.35	10.3	4.8	33	54	14	silt loam
9	NY	350	1000	7.8	17	7.3	306	0.43	17.3	7.2	35	44	21	loam
					18	7.2	402	0.43	17.0	5.4	32	47	20	loam
10	NY	350	1070	7.8	19	6.6	99	0.15	11.8	6.0	23	53	24	silt loam
					20	6.1	43	0.26	11.8	9.3	34	47	19	loam
11	NY	270	920	7.7	21	6.4	137	0.28	10.2	6.4	31	48	22	loam
					22	6.5	205	0.48	13.8	8.8	31	50	19	loam
12	PA	510	1050	7.7	23	6.6	27	0.33	13.2	5.5	35	36	29	clay loam
					24	6.3	22	0.24	12.7	5.4	34	35	30	clay loam
13	PA	100	1160	11.1	25	7.1	391	0.66	10.8	6.4	49	38	13	loam
					26	7.4	214	0.65	9.8	5.6	43	44	14	loam
14	PA	510	1050	7.7	27	6.5	144	0.95	10.0	4.0	47	31	22	loam
					28	6.1	45	0.38	10.6	4.0	31	38	32	clay loam
15	PA	130	940	10.7	29	6.5	41	0.14	11.9	3.7	30	40	30	clay loam
					30	6.6	81	0.14	7.8	3.0	36	45	19	loam
16	VT	220	1110	7.8	31	6.6	701	0.85	13.7	7.5	64	30	7	sandy loam
					32	5.8	52	0.16	9.1	7.4	56	37	7	sandy loam
17	VT	100	840	6.9	33	7.2	104	0.23	13.4	3.0	25	29	45	clay
					34	7.0	144	0.35	15.6	3.9	30	32	38	clay loam
					35	7.3	214	0.60	18.7	6.2	44	27	29	clay loam
					36	7.2	76	0.30	18.2	6.4	39	30	31	clay loam
					37	7.4	43	0.26	15.9	5.1	29	35	37	clay loam

ative cover / 2). For soil analyses, we took 10–12 soil cores (2.5 × 10 cm) from random locations in each pasture. Cores were composited and then analyzed for pH, phosphorus, potassium, cation exchange capacity, % soil organic matter and soil texture using standard methods by the Agricultural Analytical Services Lab, Penn State University (Table 1).

Statistical analyses

We used stepwise multiple regressions to determine whether plant species richness at the 1 m^2 and 1000 m^2 scale could be explained by various environmental variables. Independent variables used for soils included % SOM, % sand, % silt, % clay, pH, P, K, CEC., site elevation, mean annual precipitation, mean annual temperature and age of the pasture since conversion from farmland. For the categorical variables describing farm management practices, we used Analysis of Covariance (ANCOVA) to test for differences in richness at the 1 and 1000 m^2 scales. We conducted one way ANCOVAs on each of the following variables: (1) farm type (beef/dairy), (2) stocking density (animals per unit area), (3) type of fertilizer used (NPK/urea/manure/none), and subjective ratings of grazing intensity (high/low) and fertilizer use (high/low/none). These subjective categories were based on information provided by the respective producers. All the continuous variables describing soils and climate listed above were treated as covariates for each ANCOVA. Pastures were considered the experimental unit (n=37).

Results

We sampled a diverse array of pastures in 1998 that encompassed a broad range of climatic and edaphic conditions (Table 1). A total of 161 plant species was positively identified (Figure 1, Appendix 1). We could not accurately classify some genera (e.g., *Solidago*, *Cyperus*) to species in many cases so these species were lumped together. White clover (*Trifolium repens* L.), dandelion (*Taraxacum officinale* Weber ex Wiggers), broadleaf plantain (*Plantago major* L.), bluegrass (*Poa pratensis* L.), red clover (*Trifolium pratense* L.), orchardgrass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), English plantain (*Plantago lanceolata* L.) were found most frequently across northeast pastures. *Trifolium repens, Poa pratensis, Dactylis glomerata, Taraxacum officinale* and tall fescue (*Festuca arundinacea* Sherber) had some of the highest percent importance values on average. Approximately 90% of the species richness was accounted for by infrequent annual and perennial weedy plants with mean importance values below 5% (Figure 1).

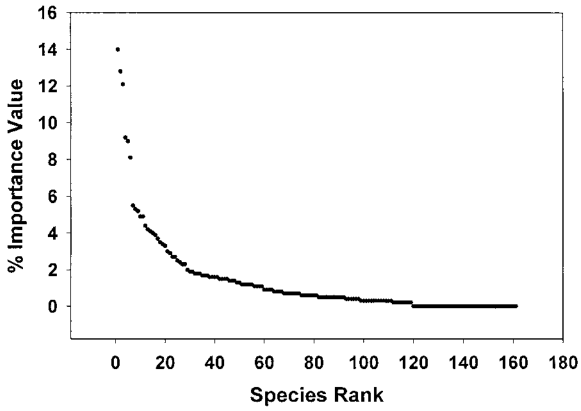

Figure 1. Dominance-diversity curve sensu (Whittaker 1965) of all pasture species encountered across the northeast US.. Percent importance values for respective species were calculated by summing the mean percent cover and mean frequency of each species.

Species richness across all pastures averaged 31.7 ± 1.1 / 0.1 ha. Perennial forbs were the most diverse functional group followed by perennial grasses, annual forbs and legumes (Figure 2). We found few annual grasses, biennials and woody plants in northeast pastures. Overall, the dominance-diversity relationships at the pasture scale resembled those at the regional scale (Figure 1). Pastures typically supported one or two dominant and subordinate species with the remainder of the richness accounted for by transient, weedy species. We arbitrarily assigned subordinate species importance values between 5 and 10% and we classified transient species as those species with <5% importance value (Grime 1998).

Stepwise multiple regression was used to determine whether environmental variables or pasture age could explain trends in plant richness. Only soil phosphorus ($R^2 = 0.38$, $F = 13.01$, $P < 0.001$) and % SOM ($R^2 = 0.07$, $F = 4.57$, $P = 0.039$) entered into the stepwise regression ($P < 0.10$) at 1 m^2 scale. These variables explained 45% of the variation in species richness at the 1 m^2 scale. Soil phosphorous explained the bulk of this variation and was inversely related to species richness (Figure 3). No variables entered the model at the 1000 m^2 scale.

Analysis of covariance revealed only one significant effect among the farm management variables

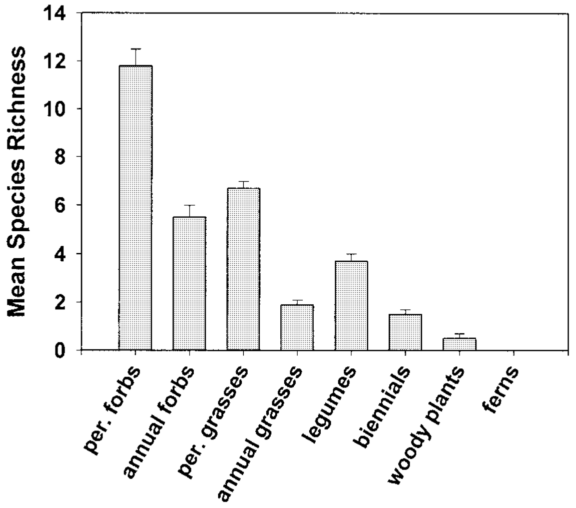

Figure 2. Mean species richness of various plant functional groups at the pasture scale (1000 m^2) . Functional groups included perennial forbs, annual forbs, perennial grasses, legumes, biennials, woody plants and ferns. Bryophytes occurred infrequently in these pastures and were not included in the survey.

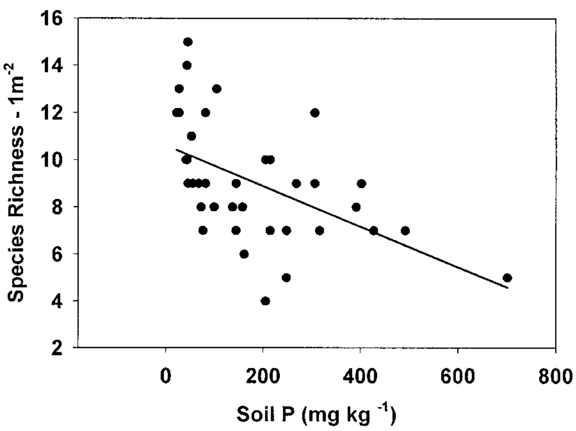

Figure 3. Plant species richness regressed against soil phosphorus at the 1 m^2 scale. Simple linear regression equation: y = 10.60 - 0.0096 (x): F = 13.01, P = 0.001, df =1.35).

tested (farm type, stocking density, grazing intensity, fertilizer use, and the type of fertilizer). At the 1 m^2 scale only, we found that species richness was reduced in intensely grazed pasture (7 $\pm$ 0.47) compared with less intensively grazed pasture (10 $\pm$ 0.51) (F =10.84, P=0.0024, df =1,32). These were subjective ratings of grazing intensity made from observations and previous knowledge about the site's grazing history. In our comparison of grazed vs ungrazed lands in the eastern US, we found that ungrazed old fields showed a distinct trend towards increased diversity after abandonment (Figure 4A). In our grazed pastures, diversity

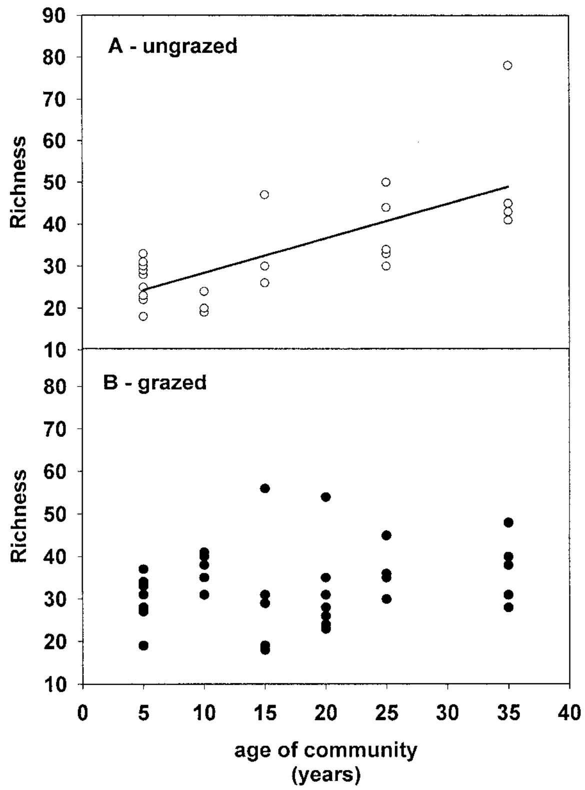

Figure 4. Species richness of ungrazed lands in the eastern US regressed against their age since abandonment from agriculture (A). Linear regression - $y = 20.21 + 0.82(x)$, $F = 26.20$, $P < 0.0001$, df = 24). Data for (A) were taken from Oosting 1942, Bazzaz 1968, 1975, Mellinger and McNaughton 1975. (B) Relationship between species richness and age of grazed pastures surveyed in 1998. Age in this case refers to the time since pasture was converted from crop land Slope of regression line was not significantly different than zero (F = 1.25, P = 0.27, df = 35).

remained constant through time since pastures had been converted from crop land (Figure 4B).

Discussion

Grazed pastures in the northeast typically consisted of several dominant and subordinate species (e.g., *Trifolium repens, Poa pratensis, Taraxacum officinale*) and a random assortment of transient species that made up the bulk of species richness. Land management, climate and soil characteristics were generally poor predictors of species richness across our sampling area – particularly at larger spatial scales. At the patch scale (1 m^2), species richness was inversely related to levels of soil phosphorus and positively associated with %SOM. Based on a subjective rating of grazing intensity, we found that heavy grazing reduced species richness at the 1 m^2 scale. Without grazing, abandoned cropland generally increases in diversity over time in the eastern US. Our data suggests that grazing may prevent this gradual increase in diversity. We suggest that the major determinant shaping plant richness at the pasture scale may be an interaction between the diversity of seed sources and stochastic recruitment of seedlings caused principally by the activities of large grazers.

Using the modified Whittaker sampling method (Stohlgren et al. 1995) we found that species richness ranged between 18 and 53 species with an average of 31.7 $\pm$1.1 / 0.1 ha. For comparison, we tested whether the species richness of northeast pastures was similar to grazed grasslands in the western US that were sampled using the same method (Stohlgren et al. 1998; Stohlgren et al. 1999a, b). We found no statistical differences between regions at either 1 m^2 scale (One Way ANOVA, $F = 2.45$, $P = 0.13$, df $=1,29$) or 1000 m^2 scale ($F = 1.60$, $P = 0.21$, df $= 1,29$) (Figure 5). Interestingly, the fundamental composition of the grasslands in these two regions differ. The richness of western grasslands is dominated by native herbaceous species ($> 70\%$) with a small component of exotic or nonnative species (Stohlgren et al. 1998, 1999a). Northeast pasture lands are almost entirely made up of nonnative species (Gleason & Cronquist 1991). The species richness similarity between these two regions suggests that there may be some fundamental characteristics of grassland plants, or grazed communities, that confines species richness to a similar range of values.

Most studies from the eastern US report a gradual increase in species diversity after crop land is abandoned from agriculture (Oosting 1942; Bazzaz 1968; Bard 1972; Bazzaz 1975; Mellinger & McNaughton 1975). Our data suggests that if crop land is converted to pasture instead, species richness remains similar to abandon agricultural land in the first years of succession when these lands are dominated by annual weedy species (Figure 4) (Bazzaz 1968). After the first several years of abandonment, plant diversity generally increases mainly because invading woody plants increase the vertical and horizontal heterogeneity of ungrazed fields thus allowing a greater array of species to coexist (Bazzaz 1975). In our pastures, continual grazing, and occasional mowing for hay harvest, prevents establishment of large tree and shrub species that would otherwise become prevalent 25–30 years after cropland abandonment. As Figure 2 shows, woody

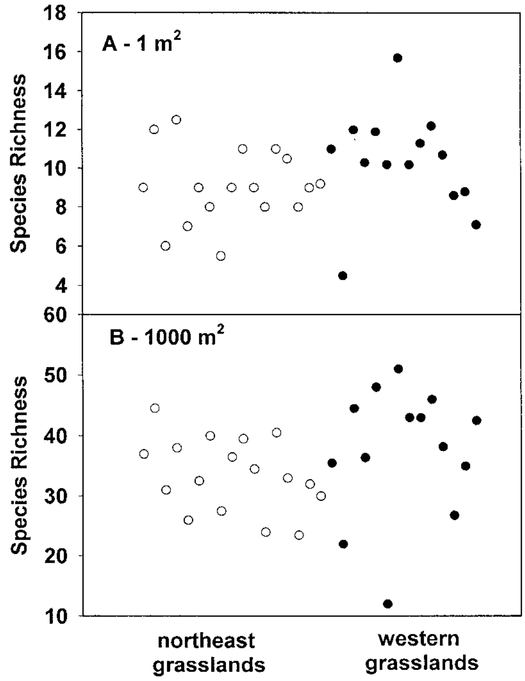

Figure 5. Species richness at 1 m^2 (A) and 1000 m^2 (B) compared between the 17 farms surveyed in this study (hollow circles) and 14 western US grassland sites surveyed by Stohlgren et al. (1998, 1999a, b) (filled circles). The 14 western US grasslands included (1) Bighorn Basin Resource Area, Wyoming, (2) Charles M. Russell National Wildlife Refuge, Montana, (3) Grand Teton National Park, Wyoming, (4) Gunnison Resource Area, Colorado, (5) Rocky Mountain National Park, Colorado, (6) Uncompahgre Basin Resource Area, Colorado, (7) Pryor Mountain Wild Horse Range, Montana, (8) Wind Cave National Park, South Dakota, (9) Yellowstone National Park, Wyoming, (10) Badlands National Park, South Dakota (two sites), (11) Pipestone National Monument, Minnesota, (12) High Plains Experiment Station, Wyoming, (13) Central Plains Experiment Range, Colorado.

plants were rare except for occasional tree seedlings. Nevertheless, enough heterogeneity seems to exist in grazed pasture to maintain richness at a constant levels though time.

We attempted to explain species richness patterns by evaluating their relationship to land management methods and environmental variables. Except for a subjective rating of grazing intensity, land management methods were not good predictors of species richness. Of the environmental variables measured, only soil P explained a significant amount of the variation in species richness. Soil P was inversely related to species richness at the 1 m^2 scale while % SOM was positively associated with species richness at this scale, although weakly. In their survey of British pastures, (Forbes et al. 1980) also found that weedy swards were associated with low P or K soils. These findings suggest that P fertilization of pasture lands may reduce weed problems in low P soils.

At larger spatial scales, soil variables were unrelated to species richness. This finding differs from (Stohlgren et al. 1998, 1999a) who found stronger positive correlations between species richness and soil fertility (e.g., soil C:N, % N) in western grasslands of the US. The range in soil fertility was probably greater in western grasslands compared to our survey. Most of our pastures had been fertilized which likely obscured a soil fertility gradients that may have existed naturally. Lastly, climatic variables (mean annual precipitation and temperature) did not explain patterns of plant richness at any scale. We suspect temperature and precipitation gradients across our sampling area probably were too low to cause measurable differences in species richness (Table 1). These climatic differences, however, did influence the composition of species richness across the region. For example, we noted more C_4 species in southern pastures compared with more northern pastures (B. Tracy, personal observation). Overall, our data suggests that some environmental variables (soil P and SOM) may influence species richness patterns in northeast pastures, but the importance of these variables is scale dependent.

We hypothesize that the diversity of seedlings recruited from soil seed banks or possibly local seed rains influenced species richness at large spatial scales. In an earlier study of 36 pastures in three northeast states, we found that more than 60% of the viable seed bank consisted of annual and perennial forbs that had low importance values in the aboveground vegetation (Tracy & Sanderson 2000). Most of these seed bank species likely represented past ecological conditions and are characterized by having pulsed seed input, possessing long- lived seed, and emerging from the seed bank only under specific conditions (Rabinowitz 1981). These kinds of annual and perennial forbs (i.e., transient species) accounted for most (∼ 90%) of the species richness in our current survey. Cattle probably have a major role in the recruitment of transient species since they increase the patchiness of grasslands through their grazing, trampling, wallowing, and waste deposition (Collins & Barber 1985; McNaughton 1985; Steinauer & Collings 1995; Knapp et al. 1999). Such patchiness facilitates recruitment of transient species from soil seed banks and seed rains and may help to increase pasture diversity indirectly (Bullock et al. 1994). We suggest that such stochastic recruitment of plants from seed reservoirs swamps out potential influences of land management and other environmental effects and thus may explain why many of these variables poorly predicted patterns of species richness.

Until this study, we knew little about the recent plant diversity of northeast pasture lands. Most of the richness (∼90%) consists of transient plants. How these 'non dominant' plants influence the functioning of pasture ecosystems is largely unknown. Transient plants, however, may play an important role in determining how rapidly plant communities reassemble themselves following disturbance (Grime 1998). If this is the case, the role of transient plants in consistently disturbed plant communities, like pasture, may be more important than we realize.

Acknowledgements

Authors would like to thank all the farmers who agreed to participate in this survey: Larry Lohr, Lawarson Sayre, Kathy Arnold, Nate Leonard, Ralph Porter, Dudley French, Ben Freund, Bill and Scott Poffenberger, Parish Jones, Harry Shearer, Bill Elkins, Rob Howland, Dave Petley, and Dave Franklin. Tom Stolghren and Sue Ellen Johnson provided helpful comments on earlier drafts of this manuscript.

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Appendix 1. Species list of the 161 species found in the survey. Species were divided in to respective functional groups and ranked according to the frequency of occurrence. Mean percent importance values (%IV) with 1 standard error are also given for each species.

Genus species	Common name	Number of pastures	Mean %IV	1 SE
Total Species (*n*=161)		Total (*n*=37)		
Annual forbs (*n*=36)				
Ambrosia artmesiifolia	ragweed	25	1.1	0.2
Polygonum aviculare	prostrate knotweed	18	1.3	0.3
Amarathus retroflexus	red root pigweed	14	0.5	0.3
Barbarea vulgaris	yellow rocket	13	0.6	0.1
Erigeron annus	daisy fleabane	13	0.5	0.2
Polygonum pensylvanicum	Pennsylvania smartweed	12	0.2	0.2
Polygonum lapathifolium	dock leaf smartweed	10	0.5	0.2
Acalypha virginica	virginia copperleaf	9	0.6	0.3
Chenopodium album	lamb's quarters	9	0.3	0.1
Galium mollugo	bedstraw	7	2.9	1.8
Stellaria media	chickweed	7	1.1	0.4
Sisymbrium officinale	hedge mustard	6	1.6	0.7
Galinsoga parviflora	quickweed	5	0.3	0.2
Lobelia inflata	indian tobacco	5	2.3	1.4
Polygonum convovulus	wild buckwheat	5	1.7	0.8
Stellaria graminea	stitchwort	5	1.7	0.8
Dianthus armeria	deptford pink	4	0.4	0.4
Euphorbia maculata	spotted spurge	4	1.7	0.9
Anagallis arvensis	pimpernel	3	0.7	0.4
Lactuca srriola	prickly lettuce	3	0.0	0.0
Lepidium campestre	field peppergrass	3	0.2	0.2
Lepidium virginicum	wild peppergrass	3	0.0	0.0
Chenopodium ambrosoides	mexican tea	2	0.0	0.0
Conyza canadensis	horseweed	2	0.0	0.0
Galeopsis tetrahit	hemp nettle	2	5.5	5.5
Portulacca olecrea	purslane	2	0.5	0.5
Thalaspi arvense	field pennycress	2	0.0	0.0
Abutilon theophrasti	velvetleaf	1	1.2	0.0
Bidens bipinnata	spanish needles	1	0.0	0.0
Capsella bursa-pastoris	shepard's purse	1	0.0	0.0
Datura stramonium	jimson weed	1	0.6	0.0
Erysimum cheiranthoides	wormseed mustard	1	0.0	0.0
Gnaphalium ugliginosum	low cudweed	1	0.0	0.0
Matricaria matricarioides	pineapple weed	1	0.0	0.0
Rorippa islandica	marsh yellocress	1	0.0	0.0
Rorippa sylvestris	yellow cress	1	0.7	0.0
Annual Grasses (*n*=12)				
Echinochloa crusgalli	barnyard grass	16	0.7	0.4
Setaria glauca	foxtail	11	1.7	0.6
Bromus secalinus	cheat grass	6	1.5	0.7
Digitaria sanguinalis	northern crabgrass	6	1.5	0.6
Panicum milliaceum	proso millet	6	1.5	0.5
Poa annua	annual bluegrass	6	0.7	0.3
Panicum dichotomiflorum	fall panicum	5	0.7	0.6
Digitaria ischaemum	smooth crabgrass	4	1.5	1.0
Eleusine indica	yard grass	3	0.9	0.6

Appendix 1. Continued

Genus species	Common name	Number of pastures	Mean %IV	1 SE
Total Species (*n*=161)		Total (*n*=37)		
Panicum capillare	witchgrass	2	1.4	0.8
Eragrostis pectinacea	carolina lovegrass	1	0.0	0.0
Lolium temulentusm	annual ryegrass	1	0.0	0.0
Biennial forbs (*n*=10)				
Arctium minus	burdock	11	0.0	0.0
Rudbeckia spp.	coneflower	7	0.3	0.2
Silene latifolia	white compion	5	0.5	0.5
Carduus nutans	musk thistle	4	0.8	0.3
Verbascum blattaria	moth mullein	3	0.0	0.0
Oenothera biennis	evening primrose	2	0.3	0.3
Tragopogon porrifora	salsify	2	0.4	0.4
Dipsacus sylvestris	teasel	1	0.5	0.0
Echium vulgare	viper's bugloss	1	0.0	0.0
Verbascum thapsus	common mullein	1	0.0	0.0
Ferns (*n*=1)				
Onoclea sensibilis	sensitive fern	1	0.0	0.0
Legumes (*n*=11)				
Trifolium repens	white clover	36	12.8	1.2
Trifolium pratense	red clover	31	3.5	0.6
Medicago sativa	alfalfa	15	3.0	1.1
Trifolium hybridium	alsike clover	15	4.4	0.7
Lotus corniculatus	birds foot trefoil	13	2.7	0.9
Medicago lupilina	black medic	10	0.9	0.5
Vicia spp.	vetch	9	1.2	0.4
Lespedeza procumbens	trailing bush clover	3	3.7	3.7
Baptista tinctoria	wild indigo	1	0.0	0.0
Lathyrus spp.	wild pea	1	0.0	0.0
Melilotus officinalis	sweet clover	1	0.0	0.0
Perennial forbs (*n*=61)				
Plantago major	broadleaf plantain	36	4.9	0.7
Taraxacum officinale	dandelion	36	8.1	0.7
Plantago lanceolata	english plantain	27	2.0	0.4
Oxalis stricta	yellow wood sorrel	24	1.1	0.2
Rumex crispus	curley dock	22	0.5	0.3
Daucus carota	queen ann's lace	18	2.3	0.5
Solidago spp.	goldenrod	17	0.5	0.2
Cerastium vulgatum	mouse ear chickweed	15	1.3	0.3
Asclepias syriaca	milkweed	14	0.2	0.1
Solanum carolinense	horse nettle	14	3.3	1.1
Prunella vulgaris	heal all	13	0.5	0.1
Ranunculus acris	tall buttercup	12	2.4	0.9
Chysanthemum leucathemum	ox eye daisy	11	0.7	0.3
Veronica serpyllifolia	thyme leaf speedwell	11	0.9	0.2
Viola spp.	violet	10	1.9	1.2
Potentilla novegia	cinqfoil	9	1.6	0.5
Rumex obtusifolius	broadleaf dock	8	0.3	0.2
Aster pilosus	awl aster	7	0.3	0.2
Cichorium intybus	chicory	6	0.8	0.8

Appendix 1. Continued

Genus species	Common name	Number of pastures	Mean %IV	1 SE
Total Species (n=161)		Total (n=37)		
Cirsium arvense	canada thistle	6	1.4	1.1
Fragaria virginiana	strawberry	6	1.6	0.9
Malva neglecta	mallow	6	0.3	0.2
Achillea millifolium	yarrow	5	0.2	0.2
Anthemis arvensis	chamomile	5	0.4	0.4
Aster novae-angliae	new england aster	4	0.0	0.0
Hieracium spp.	hawkweed	4	1.8	0.4
Glechoma hederacea	ground ivy	3	4.2	1.9
Hypericum perforatum	St. Jonhs wort	3	0.0	0.0
Leontodon autumnalis	fall dandelion	3	0.2	0.2
Linaria vulgaris	butter and eggs	3	0.0	0.0
Lysimachia nummularia	moneywort	3	0.2	0.2
Malva moschata	musk mallow	3	0.7	0.5
Physalis heterophylla	clammy ground cherry	3	0.3	0.3
Rubus spp.	raspberry	3	0.3	0.3
Rumex acetosella	red sorrel	3	1.2	0.7
Aster lateriflorus	goblet aster	2	1.8	1.1
Convolvulus arvensis	field bindweed	2	0.3	0.3
Duchesnea indica	indian strawberry	2	0.0	0.0
Erigeron pulchellus	robin's plantain	2	0.4	0.4
Eupatorium coelestinum	mist flower	2	0.6	0.6
Eupatorium perfoliatum	boneset	2	0.6	0.6
Myostis laxa	forget me not	2	0.9	0.2
Potentilla recta	rough fruited cinqfoil	2	0.5	0.5
Potentilla simplex	common cinqfoil	2	1.2	0.8
Scrophularia marilandica	eastern figwort	2	0.0	0.0
Scutellaria spp.	skullcap	2	0.3	0.3
Solanum nigrum	black nightshade	2	0.0	0.0
Stellaria alsine	bog chickweed	2	3.9	3.9
Tussilago farfara	coltsfoot	2	0.4	0.4
Verbena urticifolia	white vervain	2	0.3	0.3
Veronica officinalis	common speedwell	2	0.8	0.3
Epilobium glandulosum	N. willow herb	1	0.0	0.0
Helenium spp.	sneezeweed	1	0.0	0.0
Helianthus tuberosus	jerusalem artichoke	1	1.8	0.0
Hypericum mutilum	dwarf St. Johns wort	1	0.0	0.0
Iris spp.	iris	1	0.0	0.0
Lycopus americanus	water horehound	1	0.0	0.0
Mentha spicata	spearmint	1	0.0	0.0
Phytolacca americana	poke weed	1	0.0	0.0
Urtica dioica	nettle	1	1.9	0.0
Verbena stricta	hoary vervain	1	0.0	0.0
Perennial grasses (n = 22)				
Poa pratensis	bluegrass	35	14.0	1.5
Dactylis glomerata	orchardgrass	30	12.1	2.0
Phleum pratense	timothy	28	5.2	1.0
Festuca arundinacea	tall fescue	24	9.2	1.6
Elytrigia repens	quackgrass	21	3.4	0.5
Juncus tenuis	slender rush	20	0.6	0.1
Lolium perenne	perennial ryegrass	19	4.0	1.1
Cyperus spp.	sedge	16	0.8	0.3

Appendix 1. Continued

Genus species	Common name	Number of pastures	Mean %IV	1 SE
Total Species (n=161)		Total (n=37)		
Agrostis stolonifera	bent grass	12	2.7	1.0
Anthoxanthum odoratum	s. vernal grass	5	0.6	0.2
Muhlenbergia schreberi	nimblewill	5	0.0	0.0
Phalaris arundinacea	reed canary grass	5	9.0	4.2
Agrostis gigantea	redtop	4	4.9	2.2
Cynodon dactylis	bermuda grass	4	4.1	1.4
Cyperus exculentus	yellow nut sedge	4	0.2	0.2
Tridens flavus	purpletop	3	1.2	0.7
Holcus lanatus	velvet grass	2	1.6	1.6
Agrostis hyemalis	tickle grass	1	1.4	0.0
Andropogon virginicus	broom sedge	1	5.3	0.0
Bromus inermis	smooth brome	1	0.0	0.0
Muhlenbergia mexicana	wirestem muhley	1	0.0	0.0
Sorghum halpense	johnson grass	1	0.0	0.0
Woody plants (n=8)				
Rosa multiflora	multiflora rose	12	0.3	0.2
Crataegus spp.	crabapple seedling	3	0.5	0.4
Acer spp.	maple seeding	2	1.1	0.0
Morus alba	mulberry seedling	2	2.5	2.5
Ulmus rubra	slippery elm seedling	2	0.2	0.2
Populus spp.	cottonwood seedling	1	0.0	0.0
Fraxinus americana	white ash sapling	1	0.0	0.0
Salix spp.	willow sapling	1	0.0	0.0